



N e x t G e n H o u s i n g

**Zero** Energy Systems

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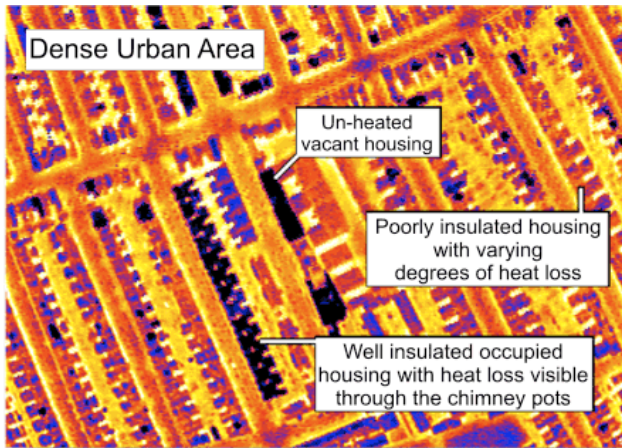
# 1 - INTRODUCTION

A zero energy building (ZEB) or net zero energy building is a general term applied to a building's use with zero net energy consumption and zero carbon emissions annually. Zero energy buildings can be used autonomously from the energy grid supply – energy can be harvested on-site. The net zero design principle is overlaid on the requested comfort of the building occupant. Generally, the more extreme the exposure to the elements the more energy is needed to achieve a comfortable environment of human use.

The zero fossil energy consumption principle is gaining considerable interest as renewable energy harvesting is a means to cut greenhouse gas emissions. Traditional building use consumes 40% of the total fossil energy in the US and European Union. In developing countries many people have to live in zero-energy buildings out of necessity. Many people live in huts, yurts, tents and caves exposed to temperature extremes and without access to electricity. These conditions and the limited size of living quarters would be considered uncomfortable in the developed countries.

Affordable housing is a major issue in Australia, especially in Sydney. Therefore zero energy systems can go a long way in minimising the running cost of households which would save families not only a lot of money but could go a long way to saving the environment. With all of the technologies available to us today as designers we must ask the question, why aren't more people looking into zero energy systems? In this chapter study we will look at different types of zero energy systems as well as passive design principles and how there's simple changes in the way we design and construct buildings can play a huge part in creating a more environmental building which not only improve the household itself but the surrounding environment as well.

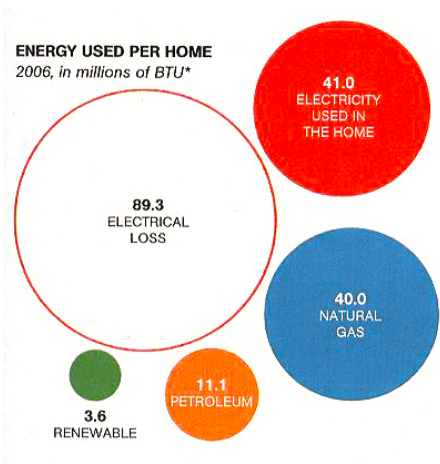
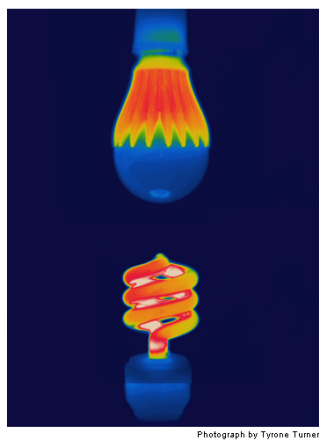
## 2 - HOUSE ENERGY CONSUMPTION



Thermographic photograph offers clues to where energy is being wasted in this older house. The roof is shown bring red as it is absorbing the most amount of heat, this is due to it being the most exposed to direct sunlight. Solutions to combat this are to use lighter colour roof materials which reflect more of the suns rays.

### 3 - HOUSE ENERGY CONSUMPTION

Electricity is the biggest source of power for U.S. homes- and for every kilowatt-hour used, 2.2 are lost as that energy is generated and sent over transmission lines. So, even small changes in our habits can scale up to big reductions in carbon emissions.



For most families, the water heater alone consumes 12 percent of their house's energy. There is an average consumption of 32 kWh of electricity and 100 cubic feet of gas to cook dinner and dry clothes. A total CO2 emission for the day is 105.6 pounds.

	Total (kgce/m²a)	Cook (kgce/m²a)	Hot water (kgce/m²a)	Lighting (kWh/m²a)	Ele. Appliance (kWh/m²a)	Air-condition (kWh/m²a)
China	8.1	2.6		6.8	6.3	2.6
US	21.1	0.8	3.1	11.2	28.0	10.4
Japan	27.8	1.2	5.4	57.3		3.8

Residential Building Energy Comparison

## 4 - ZERO ENERGY HOUSE



The major components of a net-zero energy home as part of its Net Zero Energy Home project. (Credit: General Electric)

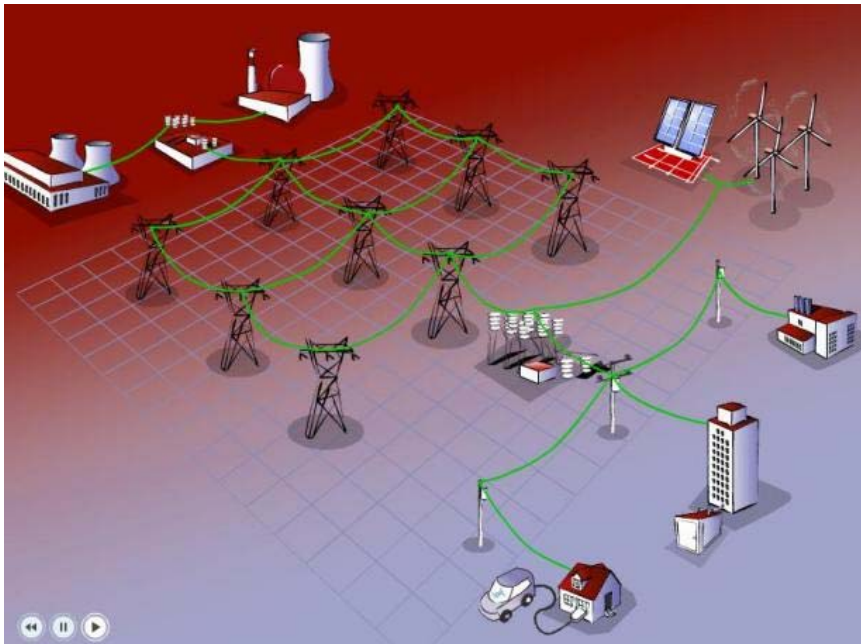
The idea behind the smart grid, which encompasses a range of technologies, is to make the electricity grid more efficient and reliable by applying information technologies and controls to the existing grid.

In addition to networked appliances, GE's Net Zero Home Project calls for on-site power generation through solar panels or wind turbines. A 3,000-watt solar panel array, which costs roughly \$30,000 to install, would be enough to supply all of a home's consumption, according to GE executives.

## 5 - ZERO ENERGY HOUSE

The complexity of decision –making in the planning of a zero-energy house requires tremendous integration of design and engineering. It is necessary to achieve relationships between architectural strategies, passive-energy design strategies and mechanical- systems integration strategies.

Design and construction industries need to openly engage the principles of architecture and passive design as fully as it engages the active technologies.



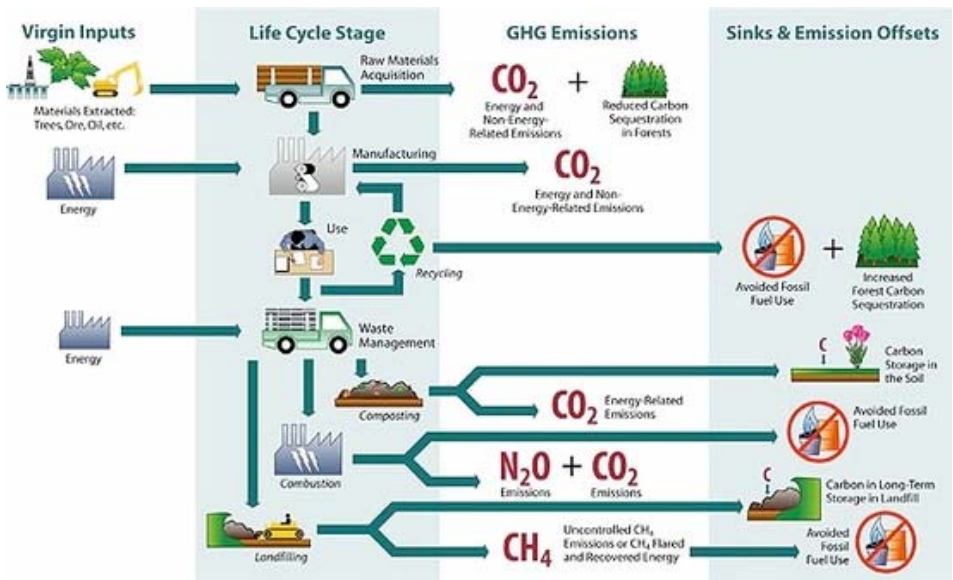
The basic idea: be more efficient, resilient, and able to use more renewable energy. (Credit: Department of Energy)

The smart grid is supposed to reduce energy waste, giving consumers better service which, and allow the grid to use more solar and wind power.

## 6 - MATERIALITY

The construction, renovation, maintenance and operation of buildings accounts for very large quantities of materials which are extracted from nature, processed, used and ultimately discarded.

The extraction, transformation, use and disposal of materials all have environmental costs, such as habitat destruction, resource depletion, energy use, air pollution, water pollution and solid waste problems.



For this reason it is very important to try and reuse as much material as we can as possible. Some materials are more easily renewed than others. For example concrete slabs take a lot of time, effort and processes to break down and sort out the steel reinforcing from the concrete and then haul it off to be broken down and reused in other things.

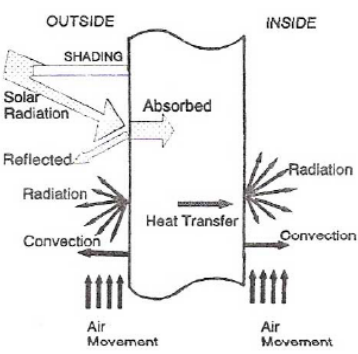
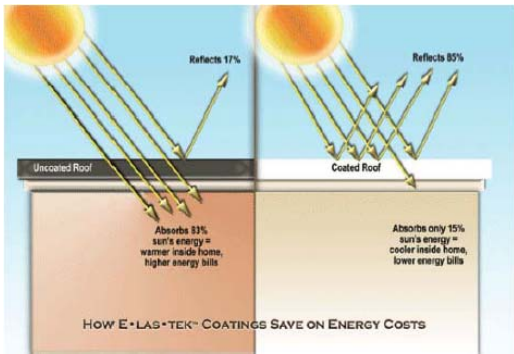
# 7 - MATERIALS HEAT TRANSFER

Thermo - physical of materials					
	material	$R$ ( $W/m^2 \cdot K$ )	$\rho$ ( $kg/m^3$ )	$C_p$ ( $kJ/kg \cdot K$ )	$\Delta x$ (m)
1	fiber board	0.052	264	0.59	0.012
2	roof tile	0.036	1890	1	0.005
3	wood				
	(a) soft wood	0.125	606	1.3	0.0125
	(b) hard wood	0.138	702	1.3	0.0125
	(c) plywood	0.138	528	1.21	0.0125
4	gypsum	0.191	880	1.09	0.012
5	window glass	1.053	2612	0.88	0.006
6	hard board plywood (standard)	0.216	1024	1.34	0.012
7	asbestos cement sheet	0.198	1860	1	0.012
8	stone				
	(a) sand stone	1.298	2000	0.79	0.026
	(b) granite	2.927	2640	0.79	0.026
	(c) marble	1.298	2640	0.8	0.026
9	light concrete				
	(a) 620 $kg/m^3$	0.16	620	0.84	0.2
	(b) 950 $kg/m^3$	0.303	960	0.84	0.2
	(c) 1120 $kg/m^3$	0.346	1120	0.84	0.2
	(d) 1280 $kg/m^3$	0.476	1280	0.84	0.2
10	concrete block	1.02	1370	0.92	0.1
11	brick				
	(a) cover with cement plaster or ceramic tile	0.807	1760	0.837	0.1
		0.807	1760	0.837	0.2
	(b) no cement plaster	1.154	1600	0.79	0.07
12	concrete	1.442	2400	0.92	0.1
		1.442	2400	0.92	0.2

## Solar absorptance of wall material and exterior color

Type of material surface	Wall material	Exterior Color	Solar Absorptance
1. High reflective surface / white painted material	Tin coating surface Aluminum plate White marble, White stone	White, Silver Reflection silver or Reflection bronze	0.3
2. light color surface	Light color marble Light color granite Light color stone	Light sky blue Light green Light yellow Light orange	0.5
3. quite dark color surface	Ceramics, no painting Brick, no painting Wood, Acetone cement Grey stone, Fiber board, no painting	Red, Orange Red, blue Green Light grey	0.7
4. dark color surface	Red brick, Dark grey concrete Roof material with dark green / dark red	Dark blue, Dark green Dark grey, Dark brown Black	0.9

All materials absorb heat, some more than others though, to minimise the amount of heat that is absorbed into a building which will minimise the amount of energy will be needed to cool the building it is very important to chose the materials for your building wisely. Some materials absorb ad store heat for a very long period of time, therefore generally these materials need to have their exposure to the sun minimised





## 8 - PASSIVE STRATEGIES

### **Orientation, Natural Ventilation, solar control, Materials**

It is the architect responsibility to create openings for natural ventilation and the correct selection of materials for a passive ventilation and thermal control.

Information obtained from a number of audit reports has shown that heat gain through building envelope is 50-60% of total.

Passive solar heating is the least expensive way to heat a dwelling. It is also:

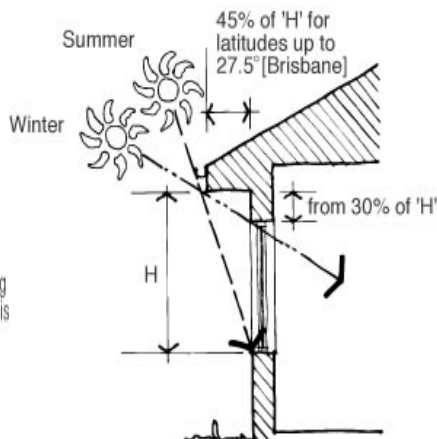
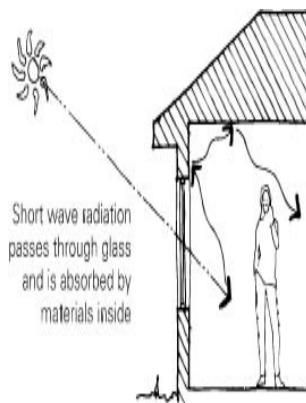
- Free when designed into a new home or addition.
- Appropriate for all climates where winter heating is required.
- Achievable when building or renovating on any site with solar access – often with little effort.
- Achievable when buying a project home, with correct orientation and slight floor plan changes.
- Achievable when choosing an existing house, villa or apartment. Look for good orientation and shading.
- Achievable using all types of Australian construction systems.

Put simply, design for passive solar heating is about keeping out summer sun and letting in winter sun. Passive solar heating requires careful application of the following passive design principles:

- Northerly orientation of daytime living areas.
- Appropriate areas of glass on northern facades.
- Passive shading of glass.
- Thermal mass for storing heat.
- Insulation and draught sealing.
- Floor plan zoning based on heating needs.
- Advanced glazing solutions.

This will maximise winter heat gain, minimise winter heat loss and concentrate heating where it is most needed.

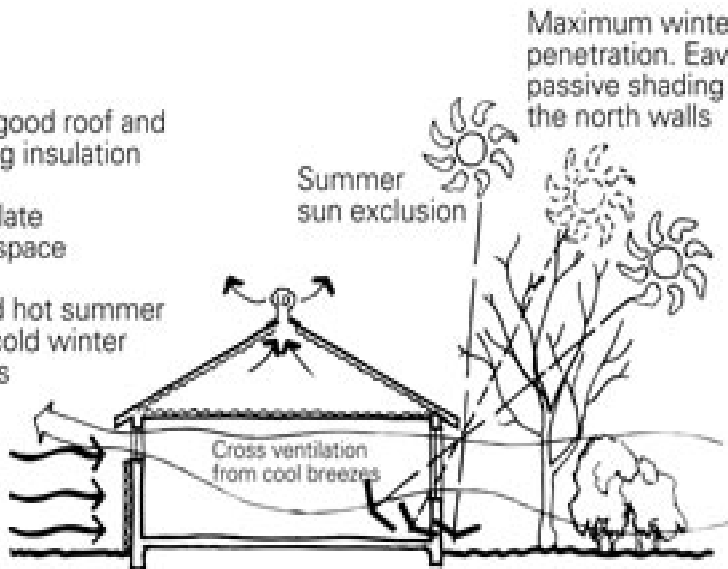
# 9 - PASSIVE STRATEGIES



Use good roof and ceiling insulation

Ventilate roof space

Avoid hot summer and cold winter winds



Heavy weight walls internally with external insulation

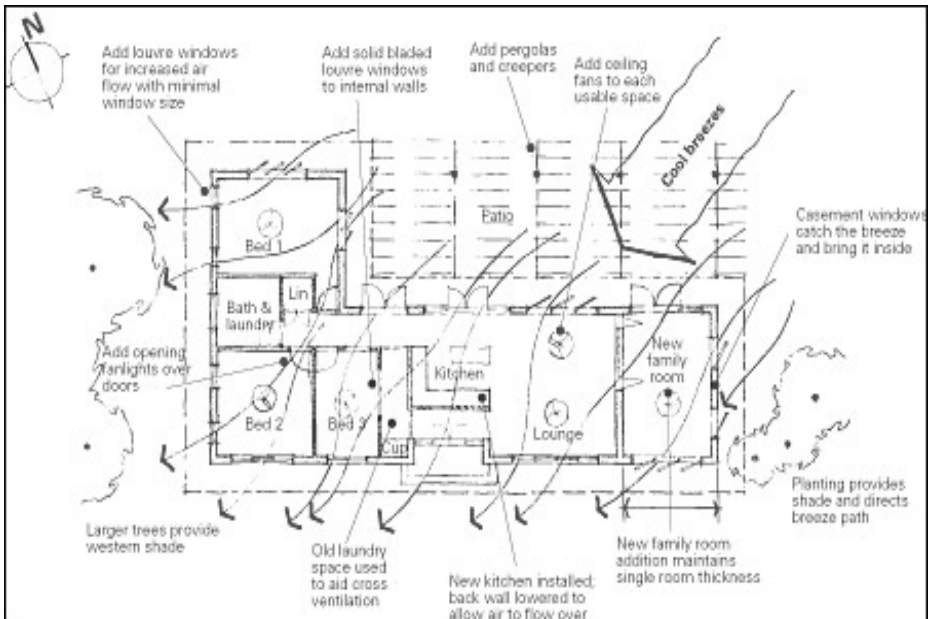
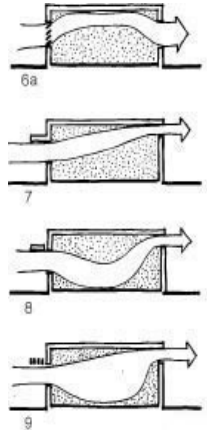


Planting to filter and direct breezes towards openings

## 10 - PASSIVE STRATEGIES

Passive strategies will embrace shading, natural ventilation, thermal storage and appropriate insulation.

- Providing heating and cooling supply devices close to occupants
- Assessing effects of partitioning and space planning on heating and cooling control
- Providing flexibility or ability to control local thermal conditions
- Designing small thermal zones
- Providing controls which correspond to interior partitioning
- Providing readily accessible and easily comprehensible controls
- Planning for the careful admission of direct sunlight
- Using thermal mass to regulate temperature variations



## 11 - ACTIVE STRATEGIES

### Rain Water Tanks



Rainwater tanks store rainwater run-off from catchment areas like your roof. In most cases, the water from your roof is funnelled along your gutters and into downpipes connected to your tank.

**Size:** The tank capacity you need depends on what you want to use it for, the size of your household and garden, your roof area and the annual rainfall in your region.

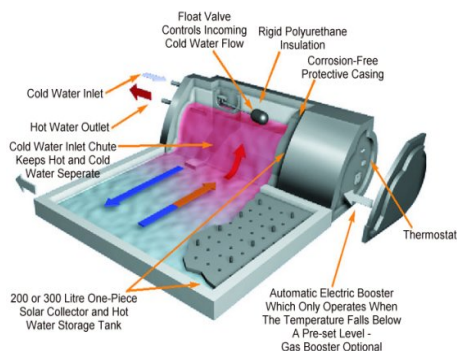
**Type:** You can choose from round, rectangular (modular) and slimline tanks. Round ones come either upright or squat, which may fit well under decking or the like. Slimline tanks are generally a bit smaller, but are popular with people who have limited space for a tank. There are also newer alternatives to the traditional shape

**Location:** To reduce water loss through evaporation from inspection holes, don't put it where it'll be in the path of the hot midday sun.

**Advantages** of rain water tanks are that they lower your water bill, minimise your impact on the environment and create an alternative water supply for your home.

## 12 - ACTIVE STRATEGIES

### Solar Hot Water System



Most solar hot water systems use solar collectors or panels to absorb energy from the sun. Water is heated by the sun as it passes through the collectors. It then flows into an insulated storage tank for later use.

In a gravity-feed solar hot water system, the storage tank is installed in the roof cavity. These systems are cheapest to purchase but household plumbing must be suitable for gravity feeding, including larger diameter pipes between the water heater and the taps. A common alternative is to use closed circuit gravity feed system to heat mains pressure water using a heat exchanger.

In active systems (also known as pump systems or split systems), solar panels are installed on the roof and the storage tank is located on the ground or another convenient location, that does not have to be above the solar collectors. Water (or another fluid) is pumped through the solar collectors using a small electric pump.

Solar hot water systems can greatly minimise the amount of energy needed to produce hot water.

## 13 - ACTIVE STRATEGIES

### PV solar cells



Photovoltaic (PV) cells are devices that convert sunlight to electricity, bypassing thermodynamic cycles and mechanical generators. PV stands for photo (light) and voltaic (electricity), whereby sunlight photons free electrons from common silicon

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load Regardless of size.

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons batteries are used in PV systems are to operate the PV array near its maximum power point, to power electrical loads at stable voltages, and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge

Advantages of PV cells are that they are environmentally friendly as the fuel they need to run (sunlight) is free. The PV system doesn't make any noise or create any pollution. Also if designed properly it requires minimal maintenance.

## 14 - ACTIVE STRATEGIES

### Green Roofs

- Reduce heating
- Reduce cooling loads on a building by fifty to ninety percent
- especially if it is glassed in so as to act as a terrarium and passive solar heat reservoir — a concentration of green roofs in an urban area can even reduce the city's average temperatures during the summer
- Reduce stormwater run off
- Natural Habitat Creation
- Filter pollutants and carbon dioxide out of the air which helps lower disease rates such as asthma see living wall
- Filter pollutants and heavy metals out of rainwater
- Help to insulate a building for sound; the soil helps to block lower frequencies and the plants block higher frequencies
- If installed correctly many living roofs can contribute to LEED points

### Financial Benefits to green roofs

- Increases roof life span dramatically
- Increase Real Estate Value

In a recent study on the impacts of green infrastructure and in particular green roofs in the Greater Manchester area, researchers found that adding green roofs will help keep temperatures down, particularly in urban areas: adding green roofs to all buildings can have a dramatic effect on maximum surface temperatures, Roof greening makes the biggest difference where the building proportion is high and the evaporative fraction is low. Thus, the largest difference was made in the town centres



## 15 - ACTIVE STRATEGIES

Green roofs can be categorized as intensive, "semi-intensive", or extensive, depending on the depth of planting medium and the amount of maintenance they need. Traditional roof gardens, which require a reasonable depth of soil to grow large plants or conventional lawns, are considered "intensive" because they are labour-intensive, requiring irrigation, feeding and other maintenance. Intensive roofs are more park-like with easy access and may include anything from kitchen herbs to shrubs and small trees. "Extensive" green roofs, by contrast, are designed to be virtually self-sustaining and should require only a minimum of maintenance, perhaps a once-yearly weeding or an application of slow-release fertiliser to boost growth. Extensive roofs are usually only accessed for maintenance. They can be established on a very thin layer of "soil" even a thin layer of rockwool laid directly onto a watertight roof can support a planting of Sedum species and mosses.

### Disadvantages

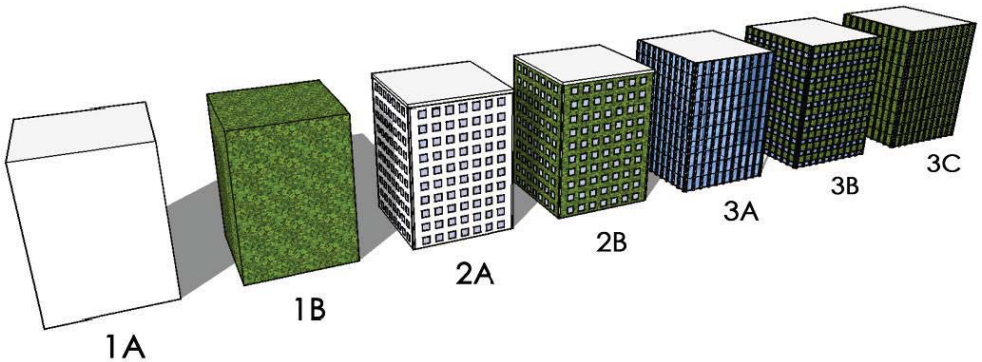
- The main disadvantage of green roofs is the higher initial cost of installing the roof. Some types of green roofs do have more demanding structural standards.
- Some kinds of green roofs also place higher demands on the waterproofing system of the structure both because water is retained on the roof and due to the possibility of roots penetrating the waterproof membrane.





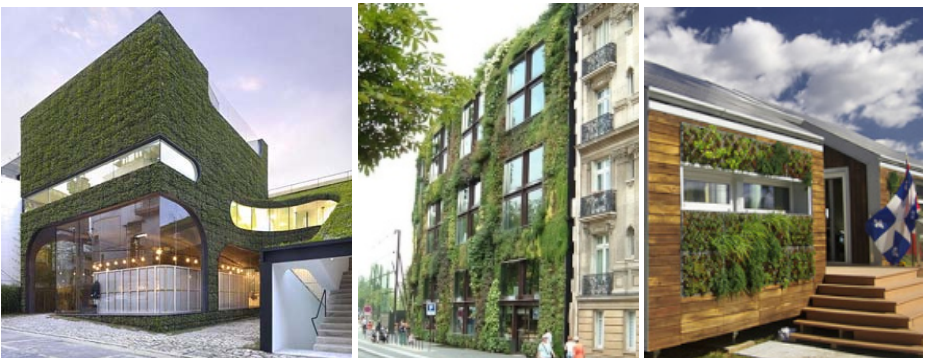
## 16 - ACTIVE STRATEGIES

### Green Walls



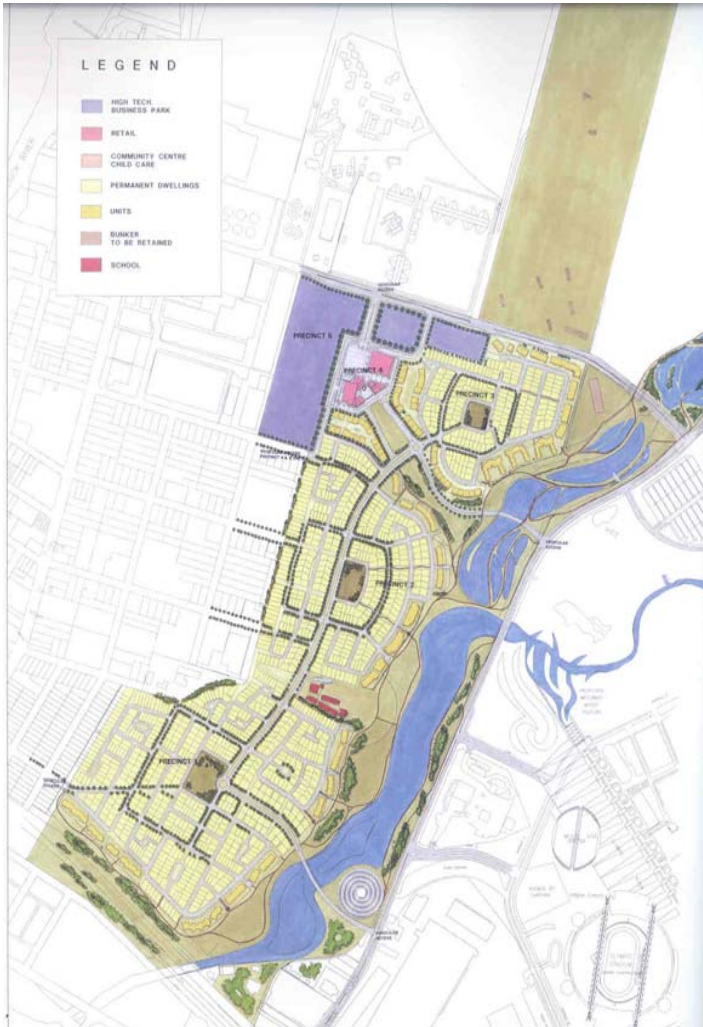
Urban spaces are being transformed into greener more environmental spaces. Rather than the traditional external building materials such as blank concrete, glass or brick walls, they are being replaced by green patches of perennials, herbs and small vegetables.

These walls besides being aesthetically pleasing to the eye, these green walls have a lot of benefits. The most obvious is the improvement in the surrounding air quality. The green walls absorb carbon dioxide and then release O<sub>2</sub> as a by product which acts as a natural air filter. It also creates and an attractive urban space while also protecting the fabric of a building from UV rays and acidic rain. These walls also help with noise attenuation and help to drone out traffic and other urban noise.



## 17 - PRECEDENT

### Environmental Community at Newington



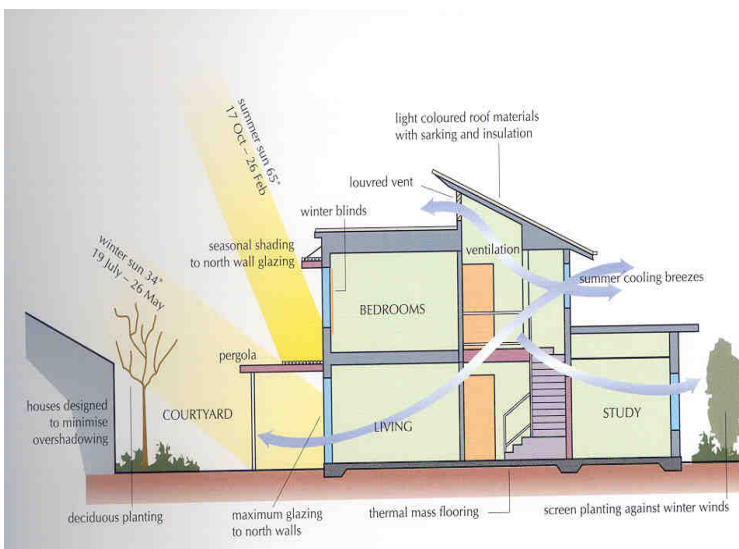
Newington is an extremely well designed Suburb which is integrated into the surrounding environment. Many design elements have been taken into consideration to make this suburb as environmentally friendly and efficient as possible; such as the use of natural ventilation and sun control, energy sources and appliances, sustainable materials, water management systems, social and cultural factors and transport.

## 18 - PRECEDENT

Newington is one of Sydney's newest suburbs. One of the main objectives when designing the layout of Newington was for it to be integrated with the surrounding environment.

The objectives the designers wanted to achieve when designing Newington was to make the suburb as environmentally friendly as possible, as well as integrating the new suburb with the surrounding environment.

### Natural Ventilation, Natural lighting and sun control:



*This section shows the principles of passive design in the Newington Apartments*

Natural ventilation is achieved through thin volumes and therefore less distance between apertures. All ground floors have excellent cross flow ventilation potential. The stairwells contribute to the stack ventilation effect for exhaustion of heat.

Sun Control devices are also presented. Sliding, adjustable louvers, horizontal steel plates, pergolas and balconies provide shade to windows and glass doors.

## 19 - PRECEDENT

### Sustainable Materials:



Dwelling Materials: Walls are clay brick in the lower part and timber framed in upper part with lightweight cladding (weatherboard and fibrous cement panels) insulated to R1.5. Clay brick has a lower embodied energy than solid concrete block.

Roofs are concrete tiles and sheet steel with sarking. Ceilings are standard plasterboard insulated to R2.5. Wool batts are used in the ceiling because of their organic content. Timber and aluminium windows were specified depending upon the usage, durability and maintenance implications. A low allergenic paint was developed with Dulux, Taubmans, Wattyls and Clean Fresh Paints (Tested by CSIRO) to reduce off-gassing and other health problems associated with conventional paints.

### Water Management System

Newington employed a dual water supply system, which will significantly reduce its water requirements. Drinking water will be supplied by Sydney water but all other water needs will be met by water reclamation and conservation strategies. All storm water is proposed to be treated in artificial wetlands, while sewage effluent will be treated in an off-site reclamation plant. Toilet flushing and landscaping irrigation would reuse this reclaimed water.

## 20 - PRECEDENT

### Sun Shading: Steel Panels

Are used on most windows in the Newington development as they allow the sun to enter the building during the winter but stop the sunlight in the summer as the sun is at a higher angle. This greatly reduces the amount of energy used to heat and cool the building during different parts of the year. Light coloured roofing and intelligent landscaping also offer protection from the sun. Planting of deciduous trees provides summer shade and allow greater sun penetration during winters.



### Energy source and appliances:

Every house in Newington is equipped with enough rooftop solar cells to generate a large proportion of electricity demands. The Photovoltaic cells, 1 KW for each house supply on average each household's daily electricity needs. The electricity needs are further reduced by 50% through the inclusion of five-star rated fitted appliances. These include showerheads, gas cook top, oven, microwave and dishwasher.

Electricity generated during the day is fed directly into the electricity grid while at night power is drawn directly from the grid. Compared to a same size and non-solar housing, Newington represents a saving of 7,000 tonnes of carbon dioxide each year and a 75% reduction in consumption of mains electricity.

Gas outlets are provided for heating. Only the cook top is gas powered. Gas boosted solar hot water panels, fitted to each house contribute the single greatest saving on energy bills. Gas boosting was preferable to electric boosting, with gas generating less than 30% of the Co2 emissions compared to an electric unit.

## 21 - PRECEDENT



Shopping centre at Newington



Business Park at Newington



New bus stop

### **Social and Cultural:**

The essential elements of a well-planned community are the basic amenities such as shopping and childcare and community centre. The main community facilities at Newington include parkland, outdoor games areas, shopping centre, childcare facilities and a primary school.

### **Transport:**

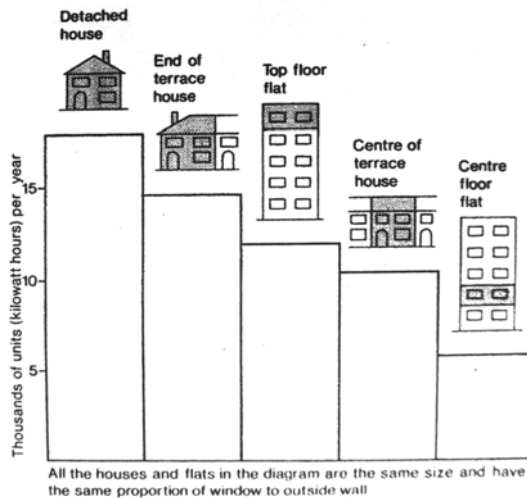
The Olympic site has a new train station connected to the main Sydney Line, a ferry terminal (5 minute bus trip) on the Parramatta River and both existing and new bus routes near and through the site.

## 22 - DENSITY

The number of households in Sydney grew by 15.5% between 1996 and 2001.

Households in the City of Sydney are generally smaller than Inner Sydney SSD and Sydney SD. Households are predominately occupied by a single person (42.4% of occupied private dwellings) or two people (36.9%). Only 20.8% of occupied private dwellings house three or more people living in them.

Reusing and adapting existing or under-utilized buildings can help rejuvenate old neighbourhoods and slow the rate of urban sprawl which destroys agricultural land and increases energy required for commuters.



**Figure 11.2**

Relationship between built form and energy use in housing. (Lothian Energy Group/BRE©.)

As can be seen in the diagram above single detached dwellings use substantially more energy than a centrally located unit in an apartment.

## 23 - DESIGN RESPONSIBILITIES

The environmental agenda will require architects and other design professionals to:

- Understand the emerging environmental agenda and develop the appropriate knowledge and skills to be able to respond accordingly on all design projects;
- Challenge existing design norms and reassess each design project on its own merits;
- Be open and receptive to emerging environmental ideas and be willing to re-evaluate best practices;
- Establish a coordinated team approach to design in which every member of the design team is, at some level, aware of and can make timely contributions to all the significant design issues;
- Look creatively at reusing existing buildings, materials and components in conjunction with a host of new materials that will become available as the building industry examines innovative ways of turning wastes into resources;
- Develop new skills, knowledge, and attitudes to support renovation work and to learn to be more curators of the built environment rather than creators;
- Examine the cost effectiveness of environmental strategies within a comprehensive analysis of total renovation costs and not simply evaluate them on the basis of the incremental cost-benefit of the strategy alone.



## 24 - CONCLUSION

Resources, climate, population, economy level and culture are different for every site; therefore strategies have to be carefully chosen for each site.

These guidelines emphasize environmentally responsible building design practices which establish the environmental agenda as fundamental design criteria and which result in innovative and progressive methods of construction and operation. Wherever possible and appropriate, design should challenge existing design norms and adopt innovative, more environmentally appropriate strategies which reduce environmental impacts and operating costs throughout the lifetime of buildings.

Zero energy systems can be used as a tool to minimise waste and the use of more raw materials, but it can also be a design tool, some of the systems we have looked at in this case study can be adapted and modified to create very interesting and aesthetic forms which further encourage the use of zero energy systems.